International Journal of Mechanical and Production Engineering Research and Development (IJMPERD)
ISSN (P): 2249-6890; ISSN (E): 2249-8001
Vol. 7, Issue 6, Dec 2017, 471-478

STUDY OF INFLUENCE OF TOOL GEOMETRY ON MATERIAL FLOW PATTERN IN FRICTION STIR WELDING PROCESS USING FINITE ELEMENT SIMULATION

PAVAN KUMAR THIMMARAJU[1],KRISHNAIAH ARAKANTI[2] & G.CHANDRA MOHAN REDDY[3]

[1] Departmemt of Mechanical Engineering,NNRG,Hyderabad India

[2] Department of Mechanical Engineering,Osmania University,Hyderabad, India

[3] Department of Mechanical Engineering, MGIT, Hyderabad, India

ABSTRACT

Material flow pattern studies are conducted during the friction stir welding process, to evaluate the influence of tool geometry on the flow characteristics. This is done considering the material movement in the case of friction stir welding is happening by material flow around the rotating tool and is considered as a viscous flow exhibiting laminar flow characteristics exhibiting non-Newtonian properties. Velocity field and the viscosity fields are considered as the criteria to differentiate the various weld zone viz. Weld nugget zone, HAZ & TMAZ. To compare the influence of tool geometry on the material flow behavior various tool pin profiles are considered and the resulting velocity distributions are compared. the results obtained revealed the tool pin geometry has a considerable effect on the weld nugget zone.

KEYWORDS: Friction Stir Welding, Material Flow, Fem, Velocity field & Tool Geometry

Received: Oct 25, 2017; **Accepted:** Nov 17, 2017; **Published:** Dec 01, 2017; **Paper Id.:** IJMPERDDEC201754

Original Article

INTRODUCTION

Friction Stir welding process has been a significant metal joining process since its invention by The Welding Institute(TWI) in 1991[1].Friction Stir welding process is a joining process which employs a tool which rotates and travels along the joining surfaces which are clamped together. The tool is non-consumable and many types of tool profiles are employed for the welding purpose. Tool geometry is defined by the diameter of the shoulder, diameter of the pin, shape of the pin and the pin length. The pin length is usually shorter than then the thickness of the plates to be welded. The pin is penetrated into the work pieces and the tool rotates and transverses along the centerline. The interaction between the work piece and the tool results in friction generating heat which in turn creates plastic deformation and the flow of the work piece material takes place in plasticized state as the tool traverses forward [2].the process is illustrated in the Figure 1.

The material flow in friction stir welding is complex in nature and mainly depends on the tool geometry, process parameters such as tool rotation speed, welding speed, tool tilt angle, axial force and properties of the material to be welded. The weld formation depends on the material flow behaviour of the materials, to be welded.

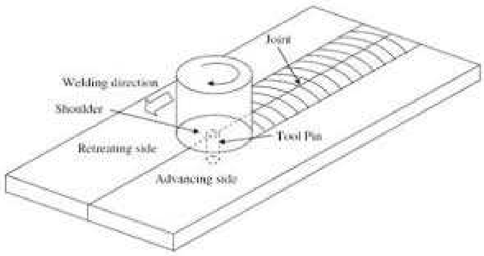

Figure 1: Schematic Showing the Position of Rotation Pin During Friction Stir Welding

As friction stir welding is a fusion welding process the welding takes place due to the intermixing of the materials for which material flow is the primary criteria which happens in solid state due to the heat generated due to friction between tool and work piece. Earlier researchers showed that the feasible way to join steel and aluminum is by Friction Stir Welding (FSW) [3]. They were able to join 2 mm thick plates and have obtained a joint tensile strength about 86% of that of Al base metal [4]. It was also demonstrated how to join Al 6061 and mild steel plates having 6-mm thickness by some researchers [5].A steel/Al weld having higher average joining strength and hardness value than base Al was obtained [6]. Intermetallic Compounds at the interface and blocky steel particles were observed in the weld. Six different phases were identified in the binary phase diagram of Fe-Al system [7] and formation of large amounts of intermetallics will drastically degrade the mechanical properties (tensile strength, etc) [8]. Complete interface micro structural analysis has been reported on the welds [9]. Various sizes of steel fragments were found in the entire region of nugget (weld) zone [10]. Recently, researchers reported a detailed analysis of how IMC layer of distinct thickness and composition can be obtained which influenced the mechanical properties of dissimilar joints of 2 mm steel and Al alloys [11]. Earlier researchers showed the processes feasible for joining aluminium to steel [12-13]

MATERIALS & METHODOLOGY

Experimentation

In this study 8mm sheets of AA 6061 are welded to 8mm The chemical of the material composition and tool description are tabulated in the Table 1 and Table 2.

Table 1: Composition of AA 6061

Element	Al	Mg	Si	Cu	Cr
Amount (wt %)	Bal.	1.0	0.6	0.3	0.2

Table 2: Description of the Tools Used in the FSW Process

Tool Number	Tool Profile	Length of the Pin(mm)	Diameter of the Pin(mm)		Diameter of the Shoulder
1	Taper	7.8	4	2	12
2	Hexagon	7.8	4		12
3	Cylindrical	7.8	4		12

Figure 2: Friction Stir Welding Experimental Setup with Provision to Measure Temperatures using Thermocouples

The friction stir welding process is carried on a modified vertical milling machine on which a specially designed fixture is mounted to hold the 100mmX200mmX8mm plates and clamed firmly. Experiments are conducted using tools of varying tool pin profiles to estimate the impact of the tool pin profile on the weld strength. Taper, hexagonal and cylindrical tool profiles are used for the welding purpose and comparison of the mechanical and macrostructures properties is done. The process parameters for tool profiles are kept constant as follows the tool rotational speed of 1400rpm and welding speed of 60mm/min. Temperatures are measured using K-type thermocouples during the welding process to estimate the heat generated during the friction stir welding process using different profiles

Process Modeling

Eulerian flow formulation is adapted in the process modeling of friction stir welding, with the following assumptions

- As we are considering aluminum as the material the elastic behavior and strain hardening are neglected to keep in view the high strains expected in the case of aluminum alloys during FSW.
- The Fluid flow that occurs during the FSW process is attributed to the pure plastic deformation without strain hardening.
- Flow stress of the material is modeling using Zener-Hollomon equation.
- Fluid flow is considered as laminar this is due to the high temperatures which are generated near the pin resulting in high rates and viscosity due to which calculated Reynolds numbers are very small.
- The 3-dimensional material flow that happens during the FSW process is modeled mathematically as a steady-state laminar flow happening around the rotating pin considering the fluid as an incompressible and non-Newtonian and the material is flowing through a stationary discretized flow zone, a stationary mesh instead of moving mesh is considered.
- The heat generated is attributed to the viscous dissipation inside the fluid.
- In this study, a validated model of the FSW process was generated using the CFD software FLUENT, with this model then being used to assess in detail the differences in flow behaviour, mechanically affected zone (MAZ) size and strain rate distribution around the tool for various tool geometries

RESULTS AND DISCUSSIONS

To determine the flow behavior of the material with change in tool geometry without altering other process parameters as mentioned above.figure.3a,3b,3c show the meshing model of various tool geometries viz. cylindrical, hexagonal and tapered tools. Similar boundary conditions are chosen for all the simulations and various contours are plotted to observe the difference I patterns.

Figure 3(a): Meshing Model of Cylindrical Tool

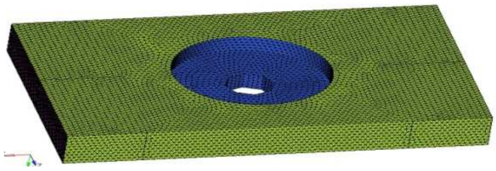

Figure 3(b): Meshing Model of Hexagonal Tool

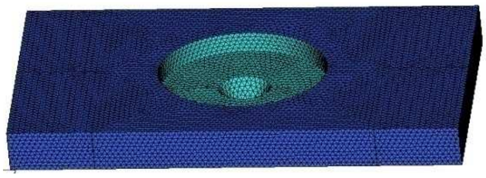

Figure 3(c): Meshing Model of Taper Tool

Figure 4a, 4b & 4c show stream lines which are different for different tool geometries .Uniform stream lines are observed for the hexagonal which is attributed to the symmetrical edges which force the material around the tool uniformly

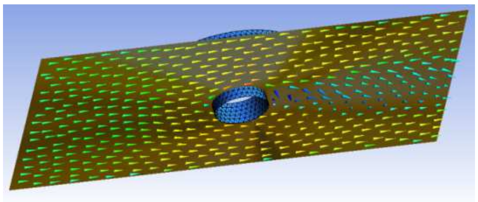

Figure 4(a): Material flow with Cylindrical Tool

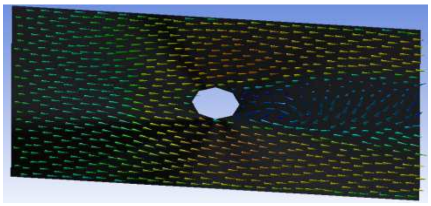

Figure 4(b): Material Flow with Hexagonal Tool

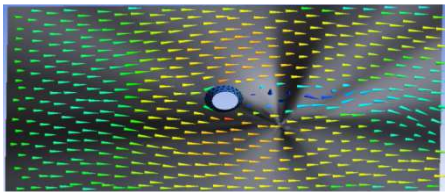

Figure 4(c): Material Flow with Taper Tool

Figure 5a, 5b & 5c show velocity contours of the FSW process with different tool profiles. Higher velocities are observed around the hexagonal tool compared with cylindrical and tapered tools. Very low velocities are observed around the tapered tool. Velocities around the hexagonal tool are high and uniform.

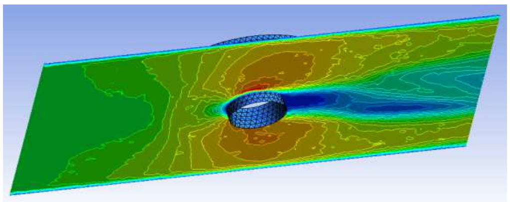

Figure5 (a): Velocity Contour of Cylindrical Tool

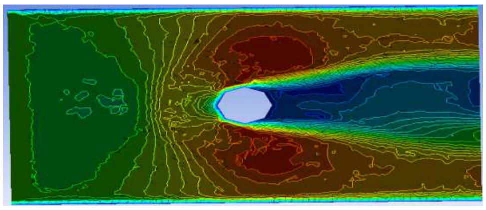

Figure.5(b): Velocity Contour of Hexagonal Tool

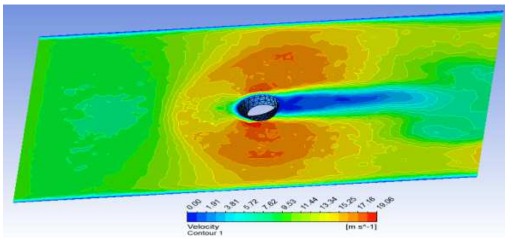

Figure 5(c): Velocity Contour of Tapered Tool

Figure 6a, 6b & 6c show pressure contours around the tool during the FSW process. It is observed the pressure is maximum on the advancing side for all the tools and the pressure on the retreating side is low for hexagonal tool.

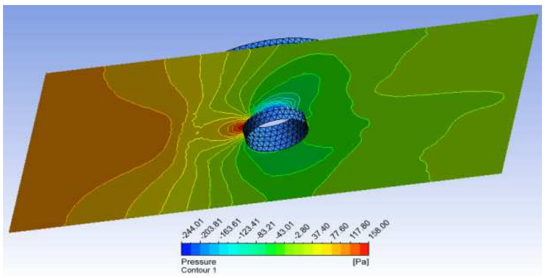

Figure 6(a): Pressure Contour of Cylindrical Tool

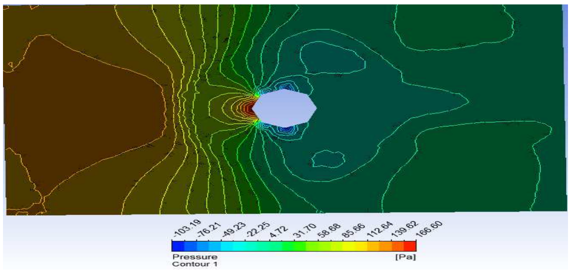

Figure 6(b): Pressure Contour of Cylindrical Tool

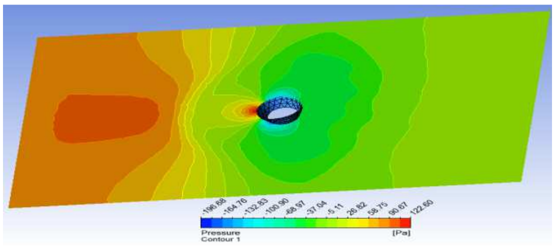

Figure 6(c): Pressure Contour of Tapered Tool

Figure 7a ,7b & 7c show the Turbulence contour for the FSW process with different tool. it is observed that for Tapered and cylindrical tools higher turbulence are noticed away from the tools which is undesirable and in the case of Hexagonal tool the turbulence contour yielded good results.

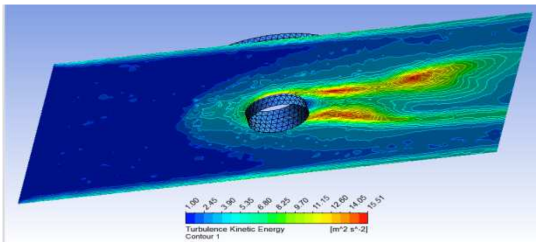

Figure 7(a): Turbulence Contour of Cylindrical Tool

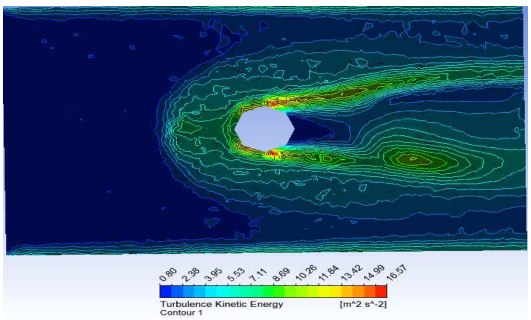

Figure 7(b): Turbulence Contour of Hexagonal Tool

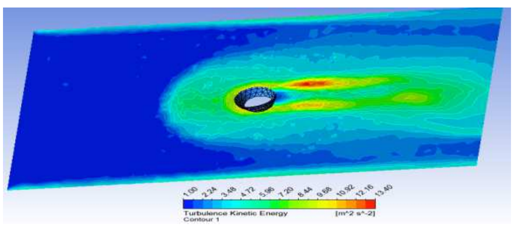

Figure 7(c): Turbulence Contour of Tapered Tool

Micro structural studies are conducted for correlating the results with the simulation results. Figure 8 a,8b,& 8c show the Macrostructure of the FSW weld zone obtained with Hexagonal tool, Microstructure of the FSW weld zone obtained with Hexagonal tool and Grain size distribution according to plain metric method of the FSW weld zone obtained with Hexagonal tool.

Metallurgical suggest the hexagonal tool yields good results and the grain structure and grain size distribution results suggest that the very fine grain size with uniform distribution is found in the nugget region which is a result of uniform distribution of the material in the weld zone which correlates with the simulation results

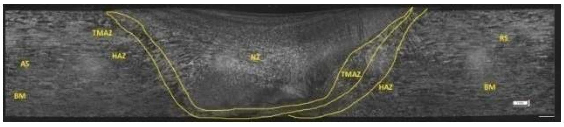

Figure 8(a): Macrostructure of the FSW Weld Zone Obtained With Hexagonal Tool

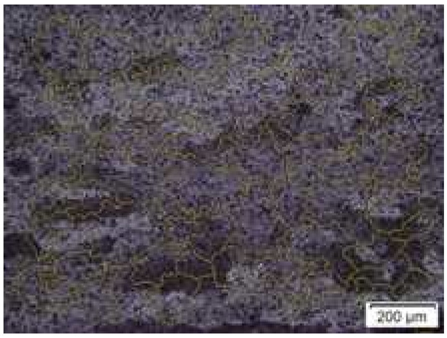

Figure 8(b): Microstructure of the FSW weld zone obtained with Hexagonal Tool

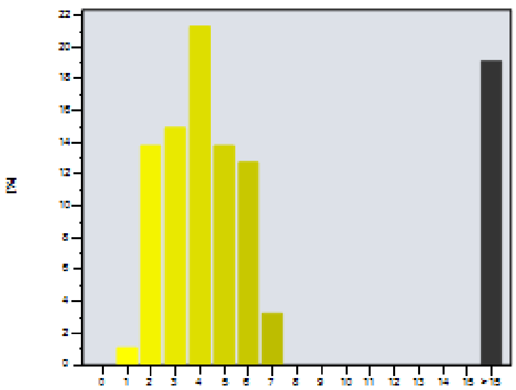

Figure 8(c): Grain size Distribution according to Plainimetric method of the FSW Weld Zone Obtained with Hexagonal Tool

CONCLUSIONS

The study shows that there are significant differences in the flow behavior, around and under the tool when the tool geometry is changed and it shows that the proposed approach is able to predict flow around the FSW tool. Good correlation is found between the simulation results and the experimental results and hexagonal tool yields good results compared with cylindrical and tapered tools.

REFERENCES

1. *Daniela Lohwasser and Zhan Chen S(2010),friction stir welding,PP.10-20,Woodhead publishing limited, www.woodheadpublishinginda.com*

2. *Hussain A K and Quadri S A P (2010),"Evaluations of parameters of friction stir welding for aluminum AA 6351 Alloy", International journal of engineering science and technology, Vol.2.*

3. *Jayaraman M, Sivasubramanian V and Lakshminarayanan A K (2009),"Optimization of process parameter of friction stir welding of cast Alluminum Alloy A 319 BY Taguchi Method", Vol.68, pp.36-43.*

4. *Shubhavardhan R N, Microstructure and Tensile Strength of Friction Stir Welding of Al-Cu, International Journal of Mechanical and Production Engineering Research and Development (IJMPERD), Volume 5, Issue 2, March - April 2015, pp. 41-50*

5. *P.A. Schweitzer, Aluminum and Aluminum alloys, MET. Mater.phys.Mech.Corros. prop.(2003)*

6. *R.S. Mishra and Z.Y. Ma, "friction stir welding and processing ", Material science and engineering, vol.R50, PP.1-78, 2005.*

7. *R.S. Mishra and M.W. Mahoney, " friction stir welding and processing ", 2007ASM International*

8. *H. Schmidt, j. Wert, An analytical model for the heat generation in friction stir welding, Modeling simul.Mater.Sci.Eng.12(2004) 143-157*

9. *M. El-Shennawy, Adel A. Omar & M. Ayad, Similar and Dissimilar Friction Stir Welding of AA7075, International Journal of Mechanical Engineering (IJME), Volume 3, Issue 4, June - July 2014, pp. 69-86*

10. *K.N. Krishna, on the formation of onion rings in friction stir welds, Material science and engineering A327(2002)246-251*

11. *Arora ,A. De and Deb Roy Toward optimum friction stir welding tool shoulder diameter. Scripta Materialia 64 (2011) 9-12.*

12. *K.Kumar and Satish V.Kalidas in: The role of friction stir welding tool on the material flow and weld formation Material science and engineering, A 485(2008)P.367-374.*

13. *P. Sevvel and V. Jaiganesh ,An detailed investigation on the role of different tool geometry in friction stir welding of various metals& and their alloys, proceeding of the international colloquium on material ,manufacturing & metrology-CMMM,August8-9,2014,pp 103-107.*

14. *Nandan R, Debroy T, BHADESHIA HKDH. Recent advances in friction stir welding process weldment structure and properties. Prog Mater Sci 2008;53;980-1023.*

15. *E.D. Nicholas, J.C. needham, M. G. Murch, p.Temple smith, C.J. Dawes W.M. Thomas, friction stir butt welding 9125978.8.1991.*